
Air filters for general ventilation —
Part 4:
Conditioning method to determine the
minimum fractional test efficiency

Filtres à air de ventilation générale —

Partie 4: Méthode de conditionnement afin de déterminer l'efficacité spectrale minimum d'essai



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 142, *Cleaning equipment for air and other gases*.

This first edition of ISO 16890-4, together with ISO 16890-1, ISO 16890-2 and ISO 16890-3, cancels and replaces ISO/TS 21220:2009, which has been technically revised.

ISO 16890 consists of the following parts, under the general title *Air filters for general ventilation*:

- *Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)*
- *Part 2: Measurement of fractional efficiency and air flow resistance*
- *Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured*
- *Part 4: Conditioning method to determine the minimum fractional test efficiency*

Introduction

The effects of particulate matter (PM) on human health have been extensively studied in the past decades. The results are that fine dust can be a serious health hazard, contributing to or even causing respiratory and cardiovascular diseases. Different classes of particulate matter can be defined according to the particle size range. The most important ones are PM₁₀, PM_{2,5} and PM₁. The U.S. Environmental Protection Agency (EPA), the World Health Organization (WHO) and the European Union define PM₁₀ as particulate matter which passes through a size-selective inlet with a 50 % efficiency cut-off at 10 µm aerodynamic diameter. PM_{2,5} and PM₁ are similarly defined. However, this definition is not precise if there is no further characterization of the sampling method and the sampling inlet with a clearly defined separation curve. In Europe, the reference method for the sampling and measurement of PM₁₀ is described in EN 12341. The measurement principle is based on the collection on a filter of the PM₁₀ fraction of ambient particulate matter and the gravimetric mass determination (see EU Council Directive 1999/30/EC of 22 April 1999).

As the precise definition of PM₁₀, PM_{2,5} and PM₁ is quite complex and not simple to measure, public authorities, like the U.S. EPA or the German Federal Environmental Agency (Umweltbundesamt), increasingly use in their publications the more simple denotation of PM₁₀ as being the particle size fraction less or equal to 10 µm. Since this deviation to the above mentioned complex “official” definition does not have a significant impact on a filter element’s particle removal efficiency, the ISO 16890 series refers to this simplified definition of PM₁₀, PM_{2,5} and PM₁.

Particulate matter in the context of the ISO 16890 series describes a size fraction of the natural aerosol (liquid and solid particles) suspended in ambient air. The symbol ePM_x describes the efficiency of an air cleaning device to particles with an optical diameter between 0,3 µm and x µm. The following particle size ranges are used in the ISO 16890 series for the listed efficiency values.

Table 1 — Optical particle diameter size ranges for the definition of the efficiencies, ePM_x

Efficiency	Size range, µm
ePM_{10}	$0,3 \leq x \leq 10$
$ePM_{2,5}$	$0,3 \leq x \leq 2,5$
ePM_1	$0,3 \leq x \leq 1$

Air filters for general ventilation are widely used in heating, ventilation and air-conditioning applications of buildings. In this application, air filters significantly influence the indoor air quality and, hence, the health of people, by reducing the concentration of particulate matter. To enable design engineers and maintenance personnel to choose the correct filter types, there is an interest from international trade and manufacturing for a well-defined, common method of testing and classifying air filters according to their particle efficiencies, especially with respect to the removal of particulate matter. Current regional standards are applying totally different testing and classification methods, which do not allow any comparison with each other, and thus hinder global trade with common products. Additionally, the current industry standards have known limitations by generating results which often are far away from filter performance in service, i.e. overstating the particle removal efficiency of many products. With this new ISO 16890 series, a completely new approach for a classification system is adopted, which gives better and more meaningful results compared to the existing standards.

The ISO 16890 series describes the equipment, materials, technical specifications, requirements, qualifications and procedures to produce the laboratory performance data and efficiency classification based upon the measured fractional efficiency converted into a particulate matter efficiency (ePM) reporting system.

Air filter elements according to the ISO 16890 series are evaluated in the laboratory by their ability to remove aerosol particulate expressed as the efficiency values ePM_1 , $ePM_{2,5}$ and ePM_{10} . The air filter elements can then be classified according to the procedures defined in ISO 16890-1. The particulate removal efficiency of the filter element is measured as a function of the particle size in the range of 0,3 µm to 10 µm of the unloaded and unconditioned filter element as per the procedures defined in ISO 16890-2. After the initial particulate removal efficiency testing, the air filter element is conditioned

according to the procedures defined in this part of ISO 16890 and the particulate removal efficiency is repeated on the conditioned filter element. This is done to provide information about the intensity of any electrostatic removal mechanism which may or may not be present with the filter element for test. The average efficiency of the filter is determined by calculating the mean between the initial efficiency and the conditioned efficiency for each size range. The average efficiency is used to calculate the ePM_x efficiencies by weighting these values to the standardized and normalized particle size distribution of the related ambient aerosol fraction. When comparing filters tested in accordance with the ISO 16890 series, the fractional efficiency values shall always be compared among the same ePM_x class (ex. ePM_1 of filter A with ePM_1 of filter B). The test dust capacity and the initial arrestance of a filter element are determined as per the test procedures defined in ISO 16890-3.

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Air filters for general ventilation —

Part 4:

Conditioning method to determine the minimum fractional test efficiency

1 Scope

This part of ISO 16890 establishes a conditioning method to determine the minimum fractional test efficiency.

It is intended for use in conjunction with ISO 16890-1, ISO 16890-2 and ISO 16890-3, and provides the related test requirements for the test device and conditioning cabinet as well as the conditioning procedure to follow.

The conditioning method described in this part of ISO 16890 is referring to a test device with a nominal face area of 610 mm × 610 mm (24 inch × 24 inch).

ISO 16890 (all parts) refers to particulate air filter elements for general ventilation having an ePM_1 efficiency less than or equal to 99 % and an ePM_{10} efficiency greater than 20 % when tested according to the procedures defined within ISO 16890 (all parts).

NOTE The lower limit for this test procedure is set at a minimum ePM_{10} efficiency of 20 % since it will be very difficult for a test filter element below this level to meet the statistical validity requirements of this procedure.

Air filter elements outside of this aerosol fraction are evaluated by other applicable test methods. See ISO 29463 (all parts).

Filter elements used in portable room-air cleaners are excluded from the scope of this part of ISO 16890.

The performance results obtained in accordance with ISO 16890 (all parts) cannot by themselves be quantitatively applied to predict performance in service with regard to efficiency and lifetime.

The results from this part of ISO 16890 may also be used by other standards that define or classify the fractional efficiency in the size range of 0,3 μm to 10 μm when electrostatic removal mechanism is an important factor to consider, for example ISO 29461.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16890-1, *Air filters for general ventilation — Part 1: Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)*

ISO 16890-2, *Air filters for general ventilation — Part 2: Measurement of fractional efficiency and air flow resistance*

ISO 16890-3, *Air filters for general ventilation — Part 3: Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured*

ISO 29464, *Cleaning equipment for air and other gases — Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 29464 and the following apply.

3.1

minimum fractional test efficiency

fractional efficiency after applying the conditioning method defined in this part of ISO 16890

Note 1 to entry: Also named as “minimum filter efficiency” or “minimum test efficiency”.

Note 2 to entry: Minimum fractional test efficiency shall be measured according to ISO 16890-2.

4 Symbols and abbreviated terms

IPA isopropyl alcohol (isopropanol)

MSDS material safety data sheet

5 General conditioning test requirements

5.1 General

This procedure is used to determine the minimum test efficiency and to test whether the filter fractional efficiency is dependent on the electrostatic removal mechanism. This is accomplished by measuring the removal efficiency of an untreated filter and the corresponding efficiency after conditioning.

Many types of air filters rely to different extents on the effects of passive electrostatic charges on the fibres to achieve higher particle removal efficiencies; particularly in the initial stages of their working life, at low resistance to airflow.

Exposure to some types of challenge, such as combustion particles, fine particles or oil mist in service may affect the action of these electric charges so that the initial efficiency may drop substantially after an initial period of service. This drop in the fractional efficiency can be reduced by a slight increase in mechanical efficiency from the collection of particles in the filtration media. The amount of the drop and the amount of the increase can vary by filter type, service location and atmospheric air conditions.

The procedure described here indirectly but quantitatively shows the extent of the electrostatic charge effect on the initial performance on a full size filter (measured according to ISO 16890-2). It indicates the level of efficiency obtainable with the charge effect removed (or minimized by IPA vapour conditioning) and with no increase in mechanical efficiency. It should not be assumed that the measured conditioned (“discharged”) efficiency always represents real life behaviour. The treatment of a filter as described in this part of ISO 16890 may affect the structure of the fibre matrix or chemically affect the fibres or even fully destroy the filter medium. Hence, this procedure may not be applicable to all types of filters. If degradation shows a visual, physical change or a resistance to airflow change of more than 10 % but minimum 10 Pa, this part of ISO 16890 is not applicable and the filter cannot be classified according to ISO 16890-1.

5.2 Test device requirements

The test device shall be designed or marked so as to prevent incorrect mounting. The complete test device (filter and frame) shall be made of material suitable to withstand normal usage and exposure to the range of temperature, humidity and corrosive environments likely to be encountered in service.

5.3 Test device selection

The test device shall be mounted in accordance with the manufacturer’s recommendations and, after equilibration to standard climatic conditions, weighed to the nearest gram. Before starting the

conditioning, the initial resistance to airflow and initial fractional efficiency shall be determined according to the measurement procedure described in ISO 16890-2.

The test device shall be a full size filter element with a nominal face dimension of 610 mm × 610 mm (24 inch × 24 inch) with a maximum length (depth) of 760 mm (30 inch). If for any reason dimensions do not allow conditioning of a test device under standard test conditions, assembly of two or more smaller devices of the same type or model is permitted, provided no leaks occur in the resulting assembly. For filters with a higher length or depth, the conditioning cabinet described in 7.1 can be scaled accordingly. The operating conditions of such accessory equipment shall be recorded.

5.4 Conditioning cabinet requirements

Critical dimensions and arrangements of the conditioning cabinet are shown in the figures of this part of ISO 16890 and are intended as guides to help construct a conditioning cabinet to meet the performance requirements of this part of ISO 16890. All dimensions shown are mandatory unless otherwise indicated. Units shown are in mm (inch) unless otherwise indicated.

The design of equipment not specified (including but not limited to the holding frame, IPA trays, conditioning cabinet surroundings and auxiliaries) is discretionary, but the equipment shall have adequate capacity to meet the performance and health and safety requirements described in [Clause 8](#).

6 Conditioning materials

The liquid for the conditioning step to discharge filter media and equalize electrostatic surface charges on the filter fibres is isopropyl alcohol (IPA, commonly known as isopropanol or 2-propanol). IPA is placed inside the conditioning cabinet to evaporate until the equilibrium of IPA vapour in ambient air is reached. So liquid IPA will not be in contact with the filter media.

This part of ISO 16890 does not claim to treat all possible related health and safety issues. It is the responsibility of the user of this part of ISO 16890 to take suitable measures for the health and safety protection of the staff before applying this method. Additionally, the responsible user shall take care that official and legal regulations are fully respected.



Isopropanol properties:

Density	0,785 5 kg/m ³
Molecular weight	60,09 g/mol
Melting point	185 K
Boiling point	355 K
Flash point	285 K
Ignition temperature	698 K
Vapour pressure	0,059 7 bar (at 298 K)/0,043 2 bar (at 293 K)/0,081 4 bar (at 303 K)

To be calculated as follows:

$$\log_{10}(P) = A - \frac{B}{T + C}$$

where

P = pressure (bar)

T = temperature (K)

A = 4,577 95

B = 1 221,423

C = -87,474

NOTE 1 bar = 100 kPa.

Explosion limits (in air) Lower concentration limit 2 % (vol.), Upper concentration limit 12 % (vol.)
both at 293 K

CAS-number 67-63-0

For the conditioning test, IPA shall have a purity of minimum 99,5 %.

7 Conditioning cabinet

7.1 General

The conditioning cabinet shall consist of a filter holding chamber and one or two IPA tray holding chambers. Each chamber may have separate doors for service. The filter holding chamber shall allow the installation of a full size filter (the test device) in a way that the filter does not touch the conditioning cabinet walls and allows air/vapour to pass around freely by diffusion. There shall be an open air passage between the IPA tray holding chamber and the filter holding chamber to guarantee that the mixture of air and IPA vapour can equilibrate in the whole conditioning cabinet volume as easily as possible. To make sure that test devices with non-rigid, self-supporting structures, like bag filters, are installed in the proper way and offer the full media surface to the air/vapour mixture, the filter holding frame is in a horizontal position and the test device is hanging vertically (dust air side of the filter to the top, clean air side to the bottom of the chamber).

7.2 Conditioning cabinet dimensions and construction materials

The conditioning cabinet shall be made of stainless or galvanized steel. IPA vapour is denser than air and can stratify within the chamber, possibly causing all areas of the filter not to be subjected to the concentration of IPA vapour. Therefore, the positioning of several IPA trays inside the IPA holding chamber of the cabinet is adjacent to the filter holding chamber, so that an equal distribution of IPA vapour within the cabinet is achieved quickly.

The conditioning cabinet shall be capable of containing a full size filter with face dimensions of 610 mm × 610 mm (24 inch × 24 inch). The maximum length/depth of the test device shall be 760 mm (30 inch). To allow the air to pass freely around the test device by diffusion, the outer filter holding chamber dimensions shall be 750 mm × 750 mm × 850 mm (29,5 inch × 29,5 inch × 33,5 inch). [Figure 1](#) shows the recommended size and dimensions of the conditioning cabinet.

Dimensions in mm

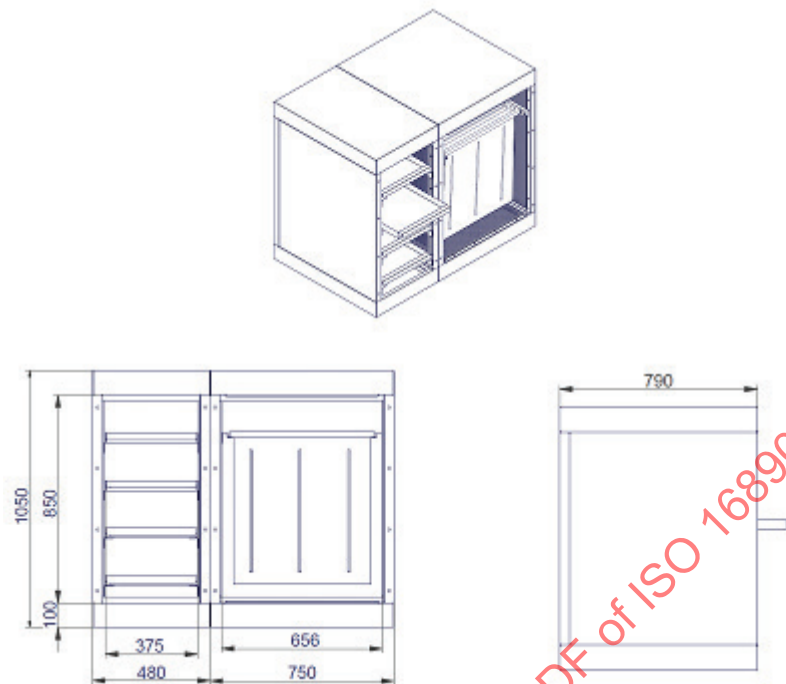


Figure 1 — Conditioning cabinet schematic drawing

To make sure that the air inside the conditioning cabinet will be saturated with IPA very quickly, a total of at least 1 dm^3 (= 786 g, 34 fl oz or 0,028 oz) liquid IPA shall be filled into the trays before starting the conditioning. The trays shall offer at least $1,0 \text{ m}^2$ (10,8 ft²) free surface area for IPA evaporation. Each tray shall be filled with liquid IPA and covered before starting the conditioning procedure. The mixture of ambient air and IPA in the conditioning cabinet shall not interact with the ambient air (proper seal).

The container with IPA shall not come into direct contact with sunlight or any other heat radiation that may alter the vapour characteristics significantly. Through respecting this and controlling the temperature and humidity within the specified ranges, there is no need for instrumentation to verify the IPA vapour concentration surrounding the test device as the air in the chamber is almost saturated with IPA vapour.

The trays with liquid IPA shall be uncovered and placed inside the filter housing. After closing the cabinet door, wait for 30 min. Then open the filter door and place the test device inside (upstream side towards IPA – vertical/horizontal).

Close the door tightly. Once the conditioning time is reached, open the door and immediately remove the test device. Finally, pull out the IPA trays, cover them and store them in the extraction hood.

7.3 Environment, temperature and relative humidity

The room air where the conditioning cabinet is installed shall be controlled at $(25 \pm 5) ^\circ\text{C}$ [$(77 \pm 9) ^\circ\text{F}$], with a relative humidity of $(40 \pm 20) \%$. The room air temperature is especially sensitive to evaporation and diffusion processes within the conditioning cabinet, and shall be reported continuously or at least hourly. The temperature measurement device shall be accurate to within $\pm 1 ^\circ\text{C}$ (1,8 $^\circ\text{F}$). The relative humidity measurement device shall be accurate to within $\pm 2 \%$. The temperature and relative humidity measurement devices shall be calibrated yearly. More frequent calibration may be needed in places where the relative humidity changes significantly by season.

Standard climatic conditions for equilibration with room air shall be $(23 \pm 5) ^\circ\text{C}$ [$(73 \pm 9) ^\circ\text{F}$] with a relative humidity of $(45 \pm 10) \%$.

8 Safety issues

This conditioning test requires the use of health hazard reagents (IPA). This part of ISO 16890 does not claim to treat all possible related health and safety issues.

It is in the responsibility of the user of this part of ISO 16890 to take suitable measures for the health and safety protection of staff before applying this method. Additionally, the responsible user shall take care that official and legal regulations are fully respected.

Some informative hints are given in [Annex A](#).

9 Test method

9.1 General

The described procedure is based on a standardized treatment with isopropanol (IPA) to evaluate electrostatic influence on the fractional efficiency of a full size filter.

The isopropanol test is made by first measuring the fractional efficiency of an untreated filter. Next, the test device is conditioned with IPA vapour. If IPA is reused, the IPA purity shall remain above 99,5 %. After the filter has been exposed to the IPA vapour, it is placed under standard climatic conditions for at least 30 min. Then the fractional efficiency measurements are repeated according to ISO 16890-2, using the same method and test aerosol as applied for the initial fractional efficiency test before conditioning. To verify that the sample is free from residual IPA, the sample is purged for 10 min with test air at $(23 \pm 5) ^\circ\text{C}$ [$(73 \pm 9) ^\circ\text{F}$] and a relative humidity of $(45 \pm 10) \%$ and the fractional efficiency test is repeated.

The isopropanol vapour treatment is made using the conditioning cabinet described in [Clause 7](#). This system includes several trays/vessels for the liquid isopropanol. The filter shall be subjected to several additional tests and it is imperative that the filter is preserved in an undamaged, uncontaminated condition for the duration of the planned total test program.

The isopropanol vapour exposure conditioning is carried out as follows:

- Equilibrate the test device under standard climatic conditions for at least 30 min. Weigh the test device to the nearest gram and measure the initial fractional efficiency and the resistance to airflow values for the new untreated device according to ISO 16890-2 (or other standard if applicable);
- Condition the filter according to the procedure described; test device exposed to saturated IPA vapour/air mixture at $(25 \pm 5) ^\circ\text{C}$ [$(77 \pm 9) ^\circ\text{F}$] for 24 h;
- Equilibrate the test device under standard climatic conditions for at least 30 min, weigh and measure the fractional efficiency and resistance to airflow. After purging for 10 min with dry, clean air, repeat the fractional efficiency test once more.

A test including conditioning on a second new test device shall be done when

- the change in weight is more than $\pm 1 \%$ or exceeds the maximum of $\pm 20 \text{ g}$,
- the resistance to airflow has changed by more than $\pm 10 \%$ or exceeds $\pm 10 \text{ Pa}$, and
- the fractional efficiency for $0,4 \mu\text{m}$ has changed more than $\pm 5 \%$ in measured efficiency percentage points after purging.

If the required accuracy above cannot be met, the test shall be stopped to find out if the filter media or filter construction is affected by the IPA vapour or if the qualification test shows a mismatch of the test rigs and procedures.

9.2 Conditioning procedure

The conditioning procedure for the test device shall follow the listed steps.

- a) Equilibrate the test device under standard climatic conditions for at least 30 min. Weigh the test device to the nearest gram and measure the initial fractional efficiency and the resistance to airflow values for the new untreated device according to ISO 16890-2 (if not yet done).
- b) Fill the trays with IPA respecting the minimum requirement of [Clause 7](#). Weigh each tray to the nearest gram (respecting safety issues according to [Clause 8](#)).
- c) Place one IPA tray after the other inside the chamber and remove its cover. Close the tray section door and wait for 30 min.
- d) Open the door of the filter section and immediately insert the test filter in place. Make sure that the filter is installed in a way that the levelling of the IPA concentration within the conditioning cabinet by diffusion is easily possible (no blockage). Close the door and tighten the curl knobs.
- e) Set the conditioning time on the timer to 24 h and start the conditioning procedure; test device exposed to saturated IPA vapour/air mixture at $(25 \pm 5) ^\circ\text{C}$ [$(77 \pm 9) ^\circ\text{F}$] run for 24 h. Room climatic conditions including barometric pressure shall be reported (and controlled if necessary).
- f) Once conditioning time is reached, open the filter door and immediately remove the test filter. Close the door and tighten the curl knobs.
- g) Equilibrate the test device under standard climatic conditions for at least 30 min.
- h) Pull out the IPA trays and place them covered inside the extraction hood. Weigh each tray to the nearest gram to determine the amount of IPA evaporated.
- i) Weigh the filter to the nearest gram and measure the fractional efficiency and resistance to airflow according to ISO 16890-2. After purging for 10 min, the fractional efficiency test is repeated once more.
- j) As an additional indication for full discharge by conditioning, a third fractional efficiency test at 50 % air flow rate shall be performed. When the efficiency curves show a variation >5 % points for $0,4 \mu\text{m}$, the same test device shall be conditioned for another 24 h. Repeat the same until the $0,4 \mu\text{m}$ efficiency measured at 100 % and 50 % air flow rate differs less than 5 percentage points.

10 Qualification

The temperature measuring and the relative humidity sensors shall be checked and calibrated a minimum of once a year.

All other instruments used in this method shall be calibrated and maintained according to the manufacturer's recommendations.

Air tightness of the conditioning cabinet shall be checked by a leakage test on a regular basis, equivalent to the leak test described in ISO 16890-2. In order to avoid unnecessary spillage of IPA-Vapour, to reduce explosion risk and exposure of persons to IPA-Vapour, the cabinet shall be sealed such that an applied overpressure of 200 Pa will not drop more than 30 Pa in 1 min. This is what an airtight construction allows and this will lead to a maximum 30 g IPA loss during a 24 h conditioning cycle.

The conditioning cabinet owner/operator shall always have a qualification testing report available documenting the results of the latest qualification testing.

11 Reporting results

Test results shall be reported using the test report format of ISO 16890-2 for fractional efficiency and resistance to airflow, which includes information about the filter manufacturer, the filter model and description.

The following additional information about the conditions during conditioning and test data shall be reported:

- a) range of room air temperature, relative humidity and barometric pressure during conditioning time with respect to the given limits;
- b) purity of IPA liquid (min 99,5 %);
- c) time of exposure/conditioning;
- d) conditioning cabinet description including photos and/or drawings with information about the main dimensions, volume of the cabinet, the amount of IPA trays, evaporation surface (number and size of the trays) and amount of IPA filled into trays with respect to the minimum criteria of [Clause 7](#);
- e) test device weight before and after conditioning and the weight of the IPA trays before and after conditioning to determine the evaporated amount of IPA;
- f) test device resistance to airflow at rated air flow rate before and after conditioning. Data values for resistance to airflow shall be reported as whole number values only (no decimal or fractions) when displayed in SI units (Pa) or to two decimal places in IP units (inch H₂O) (see ISO 16890-2);
- g) test device fractional efficiency curve at rated air flow rate before and after conditioning including measurement at 50 % rated air flow rate after conditioning. All data values for fractional efficiency shall be reported as whole number values only (no decimal or fractions);
- h) additional remarks.